A SOFTWARE TOOL FOR ASSESSMENT OF THE SPINAL FLEXIBILITY

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SUMMARY

Surgical instrumentation planning for the correction of scoliosis involves many difficult decisions, and the assessment of the spine flexibility is mainly based on measurement of the Cobb angle on radiographs. A recent study has shown a high variability in preoperative planning among a considerable group of surgeons. Thus, the purpose of this work is to present a software-tool designed to be used by clinicians as a direct aid in clinical decision making.

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a 3D deformation of the spine, which may require surgical intervention for correcting the spine deformity. The objective of the surgical procedure is to correct the spine deformities with minimal instrumented segments and prevent curve progression. The success of the surgical procedure is directly related to the preoperative planning in selecting the fusion levels, in defining the type of instrumentation, and the surgeon's ability to determine the optimal 3D corrective forces due the derotation maneuvers [1].

The human spine is an extremely complex biomechanical structure with many degrees of freedom and it is surrounded by numerous muscles, and is characterized by a high number of tendons and ligaments. Furthermore, the spine is constituted by passive and active anisotropic properties and exhibits complex boundary conditions. The characterization of the spine mechanical properties is a decisive factor in the planning of AIS surgical intervention.

Currently, the assessment of the spine flexibility and preoperative planning is mainly based on the comparison between measured Cobb angles on radiographs acquired with the patient in standing position and other situation involving a clinical test such as, e.g., lateral and fulcrum bending radiographs, which are capable of applying an unknown mechanical load to correct the spine geometry [2]. Recently, a study conducted by M. Robitaille et al., 2007 has shown a high variability in preoperative planning among a considerable group of surgeons.

The objective of the present study is to present a software-tool designed to be used by clinicians as a direct aid in clinical decision making, allowing fast and accurate reconstruction of the spinal midline and calculation of 2D local displacement and rotation fields along the spine. We believe that the use of designed software-toll (Spine Measurement System (SMS) – Alpha, ISTB, University of Bern, Switzerland) and proposed metrics will lead to further insights in the understanding of the spine flexibility.

METHODS

In order to characterize the spine flexibility, Cobb angles measurements in posteroanterior radiographs obtained from two different conditions were computed, i.e., in standing position and under fulcrum bending test, as in our example case, Figures 1A and 1B. Concave (C_1) and convex (C_2) sides of the spine were defined by cubic Bezier splines due the interactively selection of control points, i.e., three to five, and resampled with 500 equally-spaced points. Since the correspondence between C_1 and C_2 curves are pre-established, the spinal midline (C_M) can be easily computed by averaging the C_1 and C_2 curves. Then, a scaling factor was calculated between the two acquired radiographs by means of the total length of the two calculated spinal midlines. Finally, the rescaled curve was properly translated and rotated in order to establish a correspondence between the two different midlines in the image space as shown in Figure 1C. A routine was implemented in the SMS software for the calculations of Cobb angles. Additionally, three new metrics based on 2D displacement and rotation fields were computed based on the calculated and preprocessed midlines, and their normalized variations along the spine were graphically represented.

The SMS software was developed using the GNU C++ Compiler (GCC, 4.3.3), visualization toolkit (VTK-5.4.2), insight segmentation and registration toolkit (ITK-3.16.0), and QT-4.2.

RESULTS AND DISCUSSION

In this section an example based on fulcrum bending radiographs will be presented, however the proposed methodology can be extended to any other clinical test.

The developed SMS is a user friendly program allowing the precise reconstruction of the convex and concave sides of the spine as shown in Figures 1A and 1B, as well as the computation of the spinal midline and the automatic correction of scaling, translations and rotation for the establishment of correspondences between the two acquired radiographs as shown in Figure 1C.

The Cobb angles were calculated as presented in Figure 1A. Additionally, the proposed metrics, i.e., displacement in **X** and **Y** directions, as well as rotation were normalized and represented in form of graphical map, Figures 2A, 2B and 2C, respectively. The normalization is necessary, since all computations were performed in the image space, however the presented color maps provide the surgeon with the relative flexibility along the spine column.

Previous work suggests the estimation of the spinal midline by computing the centre of each individual vertebral body as the intersection points from four, manually defined points on the endplates [3]. In this context, our method presents the advantage of being less tedious and less time-consuming and presenting higher accuracy, since in AIS the patients are exposed to low-dose image acquisition protocols, thus, consequently, generating relatively low resolution images in conventional X-ray imaging, which leads to difficulties in determining the exact location of the endplates.

CONCLUSIONS

Current studies are difficult to compare since their results are influenced by the characteristics of each specific scoliotic deformity, preoperative clinical tests, and surgeon's experience. Furthermore, the magnitude and direction of the forces applied during the preoperative clinical tests for accessing the spine flexibility are unknown, because of the complex biomechanical structure and complex mechanisms of force transmission, since the mechanical load is not applied directly to the spine. Finally, the large variability in preoperative planning in AIS is questionable and highlights the need for additional clinical tests and preoperative planning systems.

The use of the software-tool and metrics proposed in this work leads to further insights in the understanding of the spine flexibility, since local and relative differences between two different situations are highlighted and represented in the form of a color map along the spine.

REFERENCES

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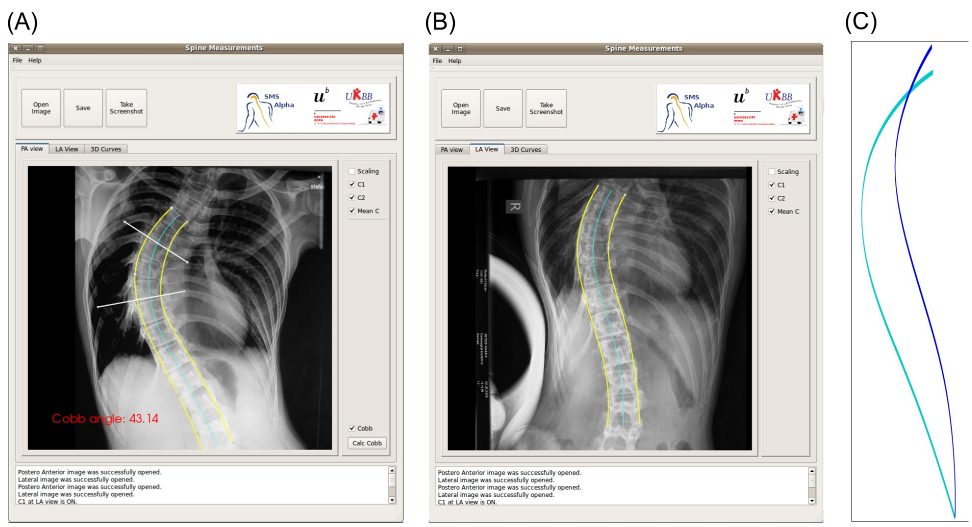

Figure 1: Developed software-tool. A: Standing position. B: Fulcrum Bending. C: Spinal midlines.

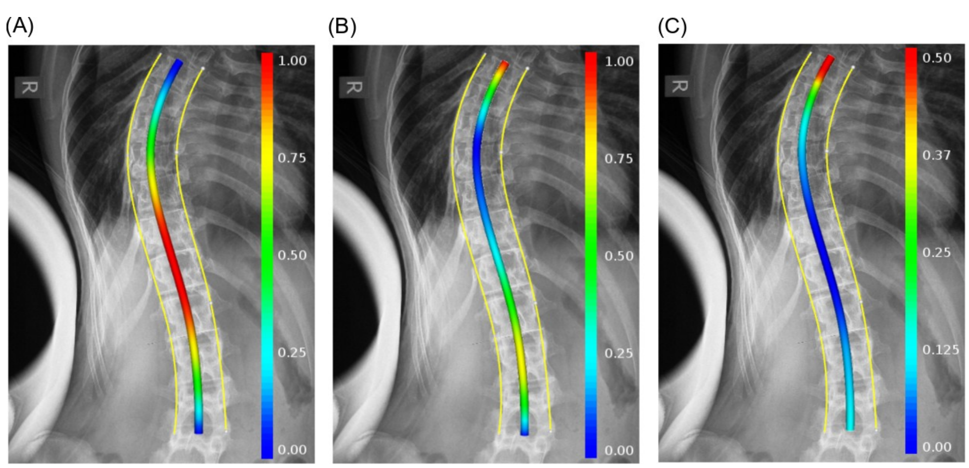

Figure 2: A: Displacement in **X** direction. B: Displacement in **Y** direction. C: Coronal rotation.